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NASA Institute for Space Studies

THEMATIC MAPPER STUDIES

BAND CORRELATION ANALYSIS

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Richard Kiang

April 1976

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GODDARD SPACE FLIGHT CENTER

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GISS THEMATIC MAPPER BAND CORRELATION STUDY

*Spectral data representative of Thematic Mapper candidate bands 1 and
3-7 were obtained by selecting appropriate combinations of bands from the JSC
24-Channel Multispectral Scanner, as indicated in Table 1. These data represent
a rather limited, but nevertheless diversified set of crop conditions as indicated
in Table 2. Of all the bands assigned, only candidate bands 4 (.74μ - .80μ) and
5 (.80μ - .91μ) showed consistently high inter-correlation from region to region
and time to time. This extremely high correlation persisted when looking at the
composite data set in a multi-temporal, multi-location domain. The GISS inves-
tigations lend positive confirmation to the hypothesis advanced by DeGasparis,
Tucker and others that TM Bands 4 and 5 are redundant.*

JSC 24-Channel MSS data were used to construct simulated TM
bands, as indicated in Table 1, for a series of interband correla-
tion studies. Note that TM band 2 was not simulated since the 24-
Channel MSS detector most closely corresponding to this wavelength
range was malfunctioning. The data used in these studies were
acquired along a flight line selected from each of the four dates
(two Intensive Test Sites). These data were considered in joint
investigations into spatial degradation conducted by LARS, Earth
Resources Laboratory (ERL) and GISS. A breakdown of the dates
and sites, indicating the number of pixels, amount of area and
crop mix is given in Table 2.

Shadowing and look angle effects tend to introduce correlations
into the data which are not inherent in the ground scenes. In order

SIMULATION OF THEMATIC MAPPER BANDS WITH JSC 24-CHANNEL MSS

PROPOSED THEMATIC MAPPER		24 CHANNEL MSS
BAND	RANGE (μ)	RANGE USED
1.	.45 – .52	.46 – .50
3.	.63 – .69	.64 – .68
4.	.74 – .80	.76 – .80
5.	.80 – .91	.82 – .87
6.	1.55 – 1.75	1.52 – 1.73
7.	10.4 – 12.5	{10.1 – 11.0 11.0 – 12.0

TABLE 1.

CHARACTERISTICS OF SITES STUDIED WITH 24-CHANNEL MSS DATA

DATE/SITES	NO. OF PIXELS	AREA	ESTIMATED CROP MIX OF TEST SITE COVERED
Finney Co., KS 6-9-75 Flight Line # 1	1,544,200	19.39 sq. mi.	Wheat (24%) Alfalfa (18%) Recently Planted (40%) Summer Fallow (12%) Other (6%)
Williams Co., ND 6-22-75 Flight Line # 2	1,384,600	17.38 sq. mil	Wheat (35%) Grass/Pasture (21%) Summer Fallow (32%) Other (11%)
Finney Co., KS 7-6-75 Flight Line # 1	1,764,000	22.15 sq. mi.	Wheat (24%) Alfalfa (18%) Corn (19%) Grain Sorghum (21%) Fallow (12%) Other (6%)
Williams Co., ND 8-15-75 Flight Line # 2	1,314,600*	16.5 sq. mi.	Wheat (35%) Grass/Pasture (21%) Summer Fallow (32%) Other (11%)

*The three segments composing this flight line are populated as follows:

$$
\begin{array}{lll}
\text{Part} & \text{I} & 438,200 \text{ pixels} \\
& \text{II} & 438,200 \text{ pixels} \\
& \text{III} & 438,200 \text{ pixels}
\end{array}
$$

TABLE 2

3

to compensate for this, unit color-vectors were constructed for each pixel by the following formula:

$$N_i' = N_i / \sqrt{\sum_{j=1}^{N} N_j^2}$$

where N_i' is the *normalized* count in the ith band. Correlation studies were conducted using both the raw and normalized (albedo compensated) data. Figures 1 through 4 represent results on a site by site and date by date basis. Note that except for cases of extremely high correlation the unit-vector representation tends to lower interband correlation (and strengthen anticorrelation) by removing some of the systematic variation in apparent albedo due to causes other than changes in ground reflectance (e.g., look angle effects, variation in instrument voltages). The albedo compensated correlations are more indicative of band redundancy than the uncompensated correlations.

The correlation coefficient in these figures was derived in the customary manner assuming linear interband relations:

$$r_{ij} = \frac{n \sum_{k=1}^{n} N_i^k N_j^k - \sum_{k=1}^{n} N_i^k \sum_{k=1}^{n} N_j^k}{\sqrt{n \sum_{k=1}^{n} \{(N_i^k)^2\} - \{\sum_{k=1}^{n} N_i^k\}^2} \; \sqrt{n \sum_{k=1}^{n} \{(N_j^k)^2\} - \{\sum_{k=1}^{n} N_j^k\}^2}}$$

In order to examine the statistical validity of the derived correlation coefficients, each line was divided into several segments of approximately equal length. Individual segment results are presented for the August 15, Williams County flight line in Figure 5. The relative interband correlations remain completely consistent from segment to segment. This spatial consistency of

FINNEY COUNTY, KANSAS – FLIGHT LINE #1 – 6/9/75
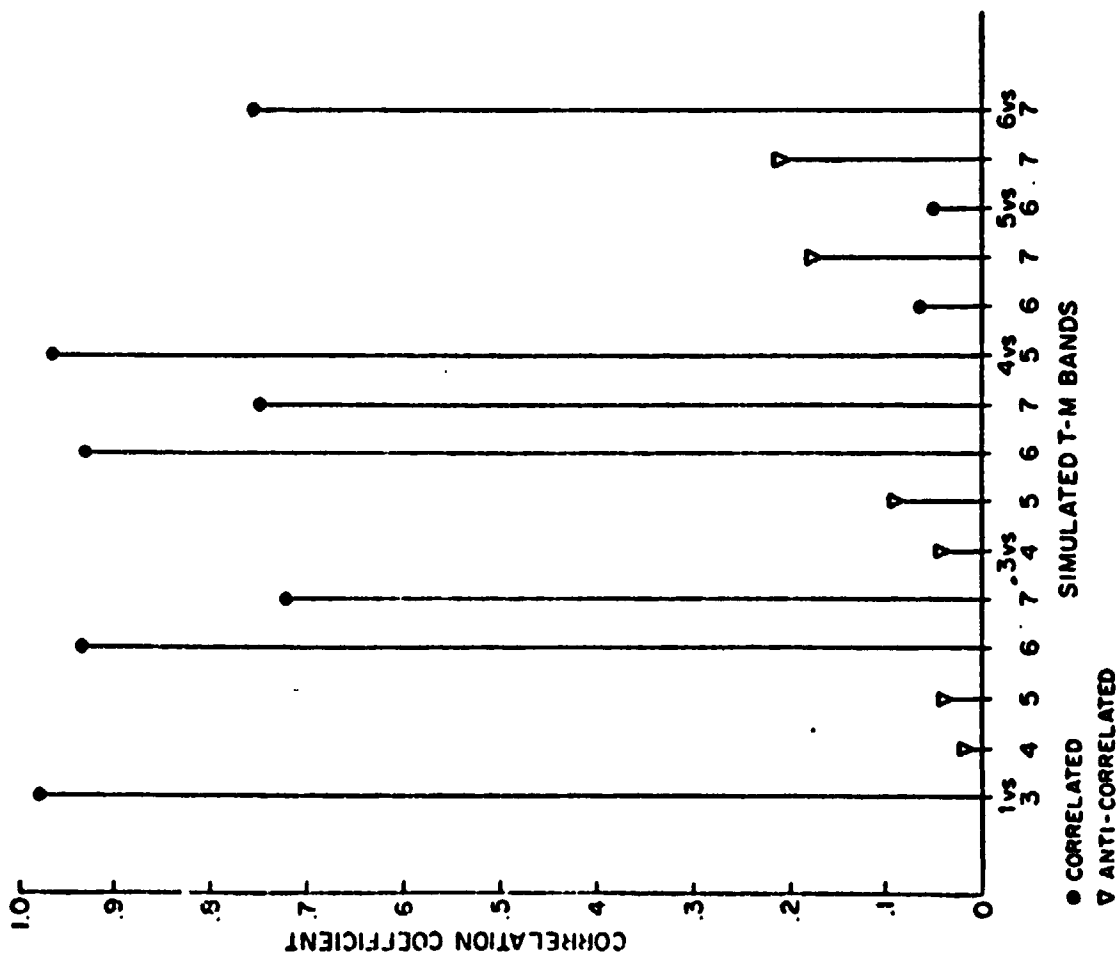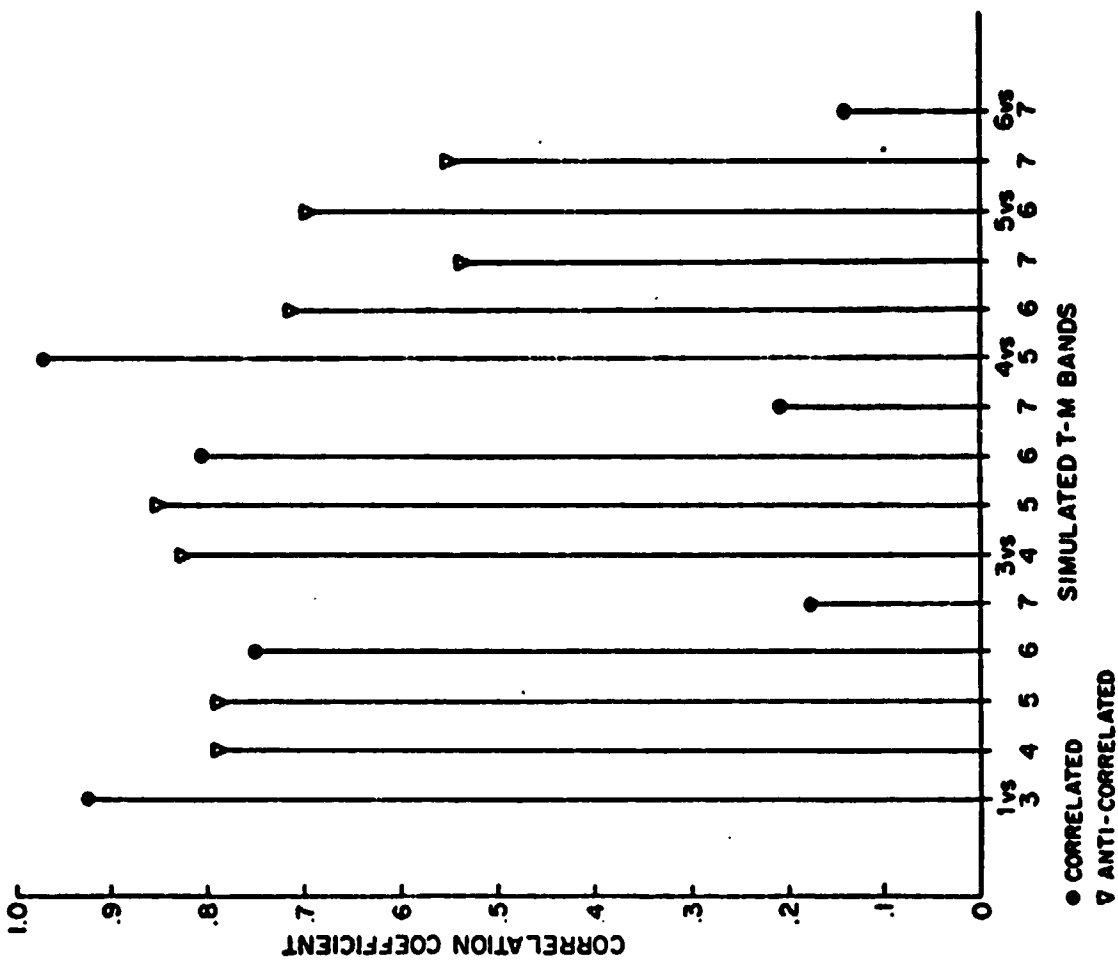
Figure 1

WILLIAMS COUNTY, NORTH DAKOTA — FLIGHT LINE #2 - 6/22/75

Figure 2

6
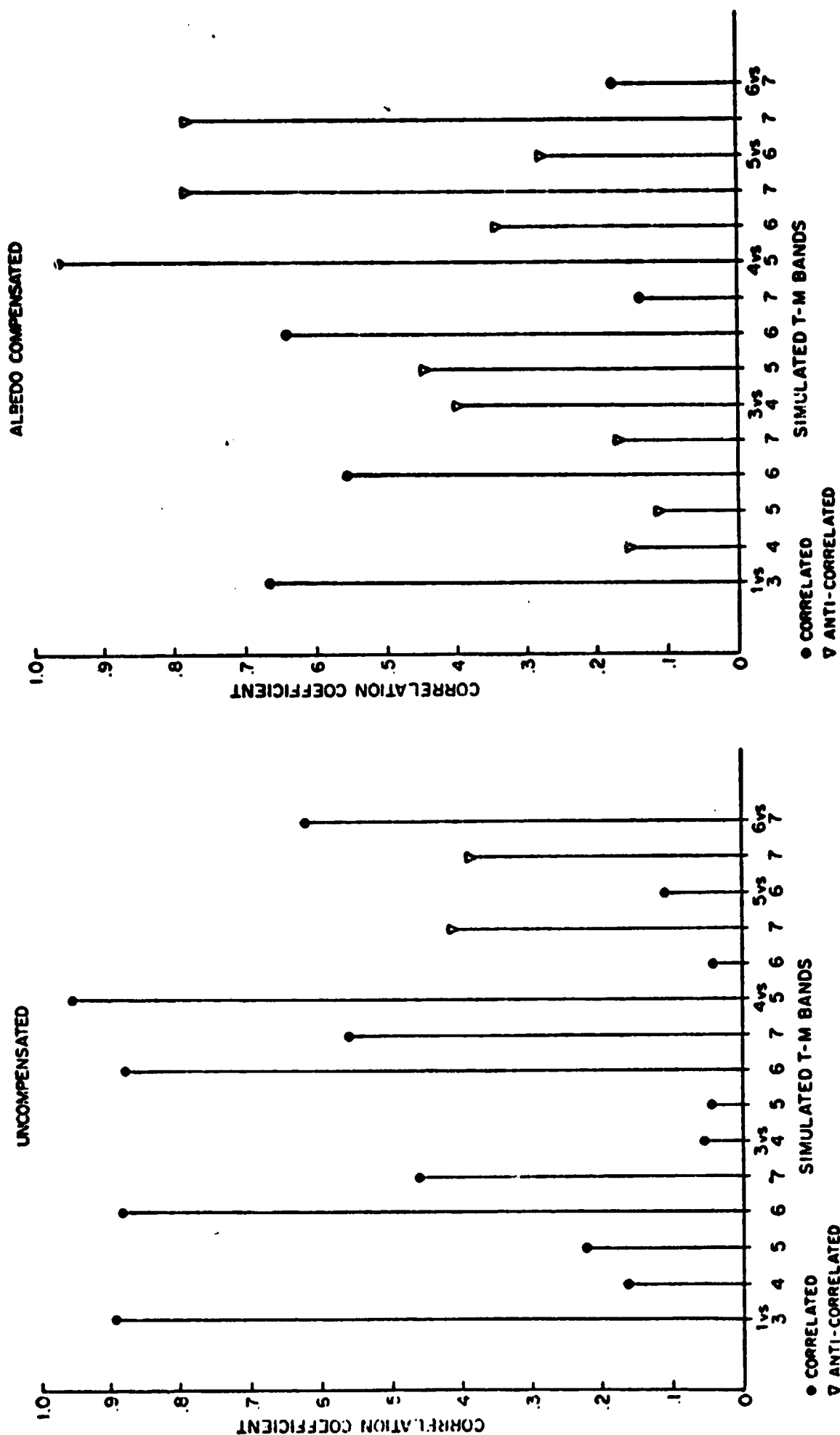
Figure 3

FINNEY COUNTY, KANSAS—FLIGHT LINE #1 - 7/6/75
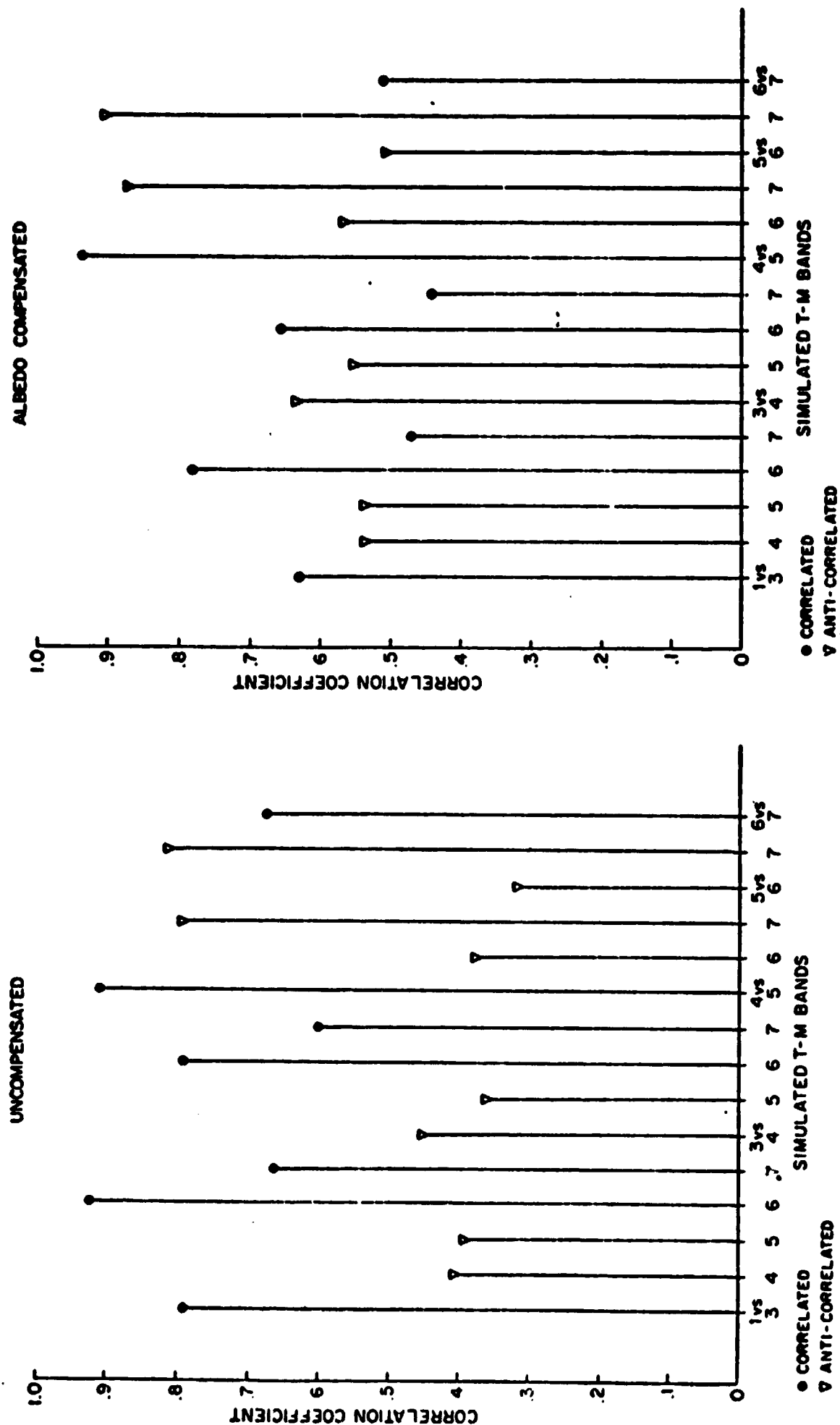
7

WILLIAMS COUNTY, NORTH DAKOTA – FLIGHT LINE #2 - 8/15/75

Figure 4

8

WILLIAMS COUNTY, N.D.—FLIGHT LINE #2—8/15/73
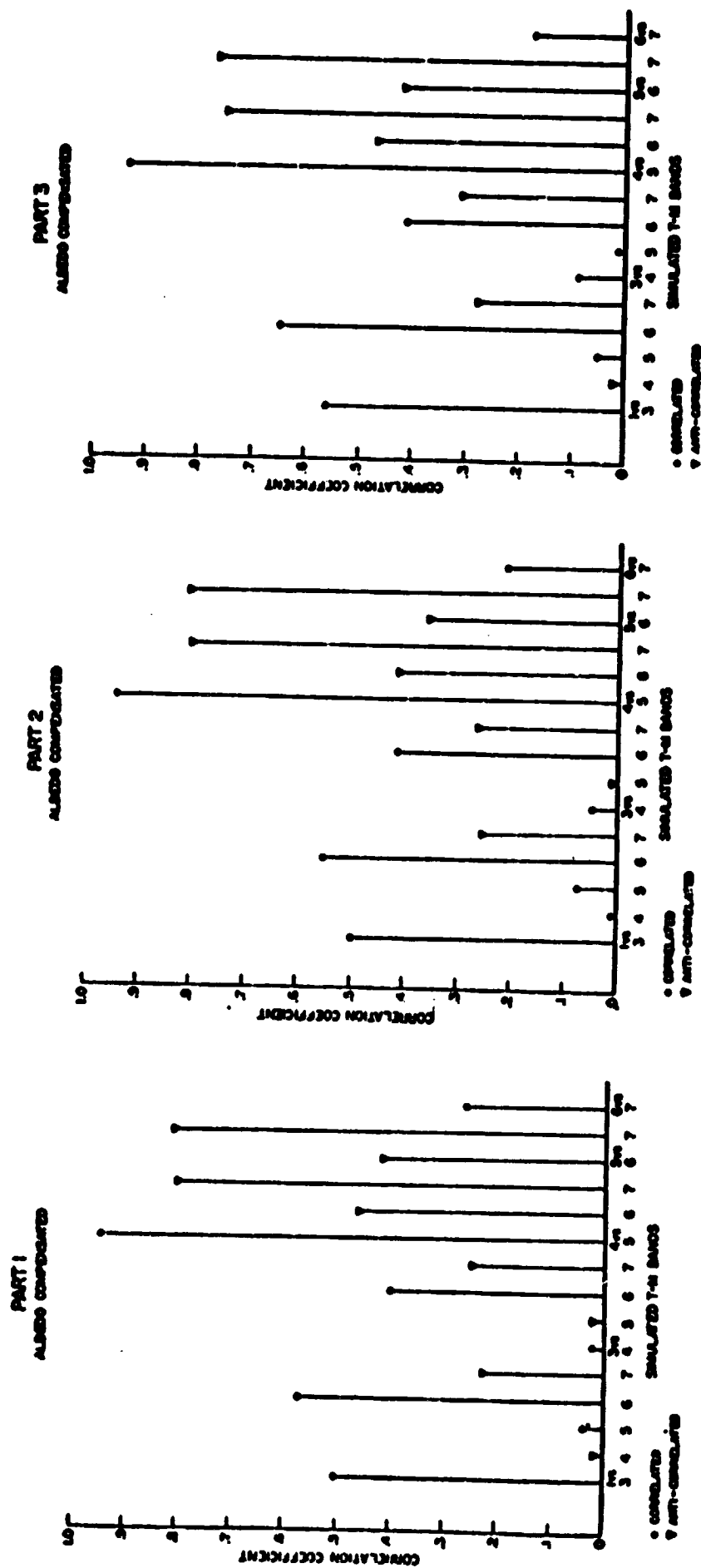
Figure 5

results was also present among the four segments of the July, Finney County flight line. However, the June 9, Finney County flight line and the June 22, Williams County flight line each displayed one anomalous segment. In both instances the segments contained appreciable cloud cover as compared to the uniformly cloud free condition for all other areas considered in this study.

The effect of cloud cover and shadow on interband correlation will be the subject of a future report.

Figure 6 represents the multi-geographic, multi-temporal data set formed by the union of all 4 data sets in the study. This data set is composed of some six million pixels representing crops such as spring and winter wheat, corn, grain sorghum, alfalfa and pasture at up to five stages of maturity.

Conclusions:

Arguments appearing in a GSFC report dated December, 1975 issued by J. Harnage through ERPO conclude that Thematic Mapper Bands 4 and 5 are highly redundant. These findings are based on laboratory and field spectra obtained under a highly restrictive set of conditions. Although these arguments are convincing when taken in context, they constitute a hypothesis when extrapolated to a multi-spectral scanner such as Thematic Mapper. Investigations by GISS using real MSS data under a variety of conditions may be considered an independent test of this hypothesis. Although the MSS data used represent a rather limited mix of cropping practices, the agricultural situations represented are precisely the

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ALL DATA SETS COMBINED

Figure 6

11
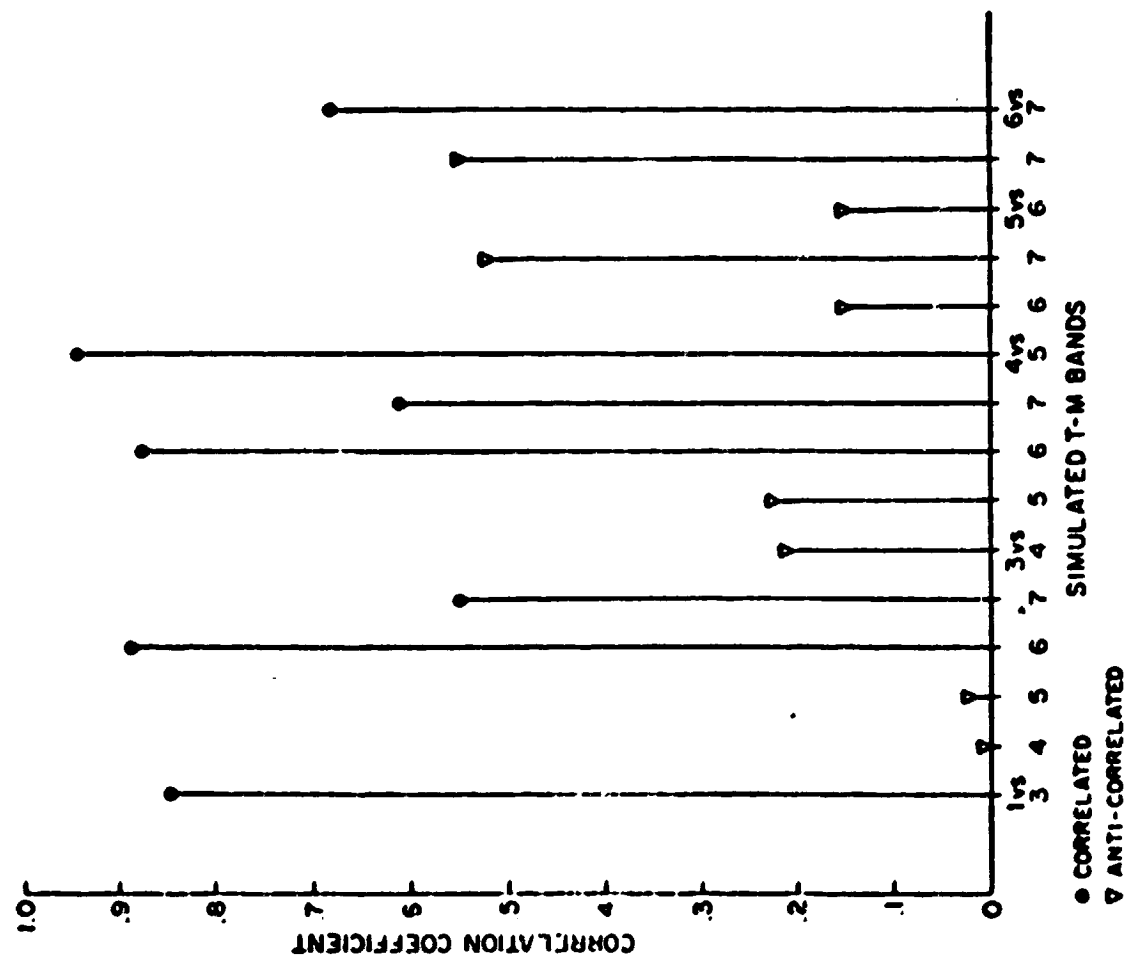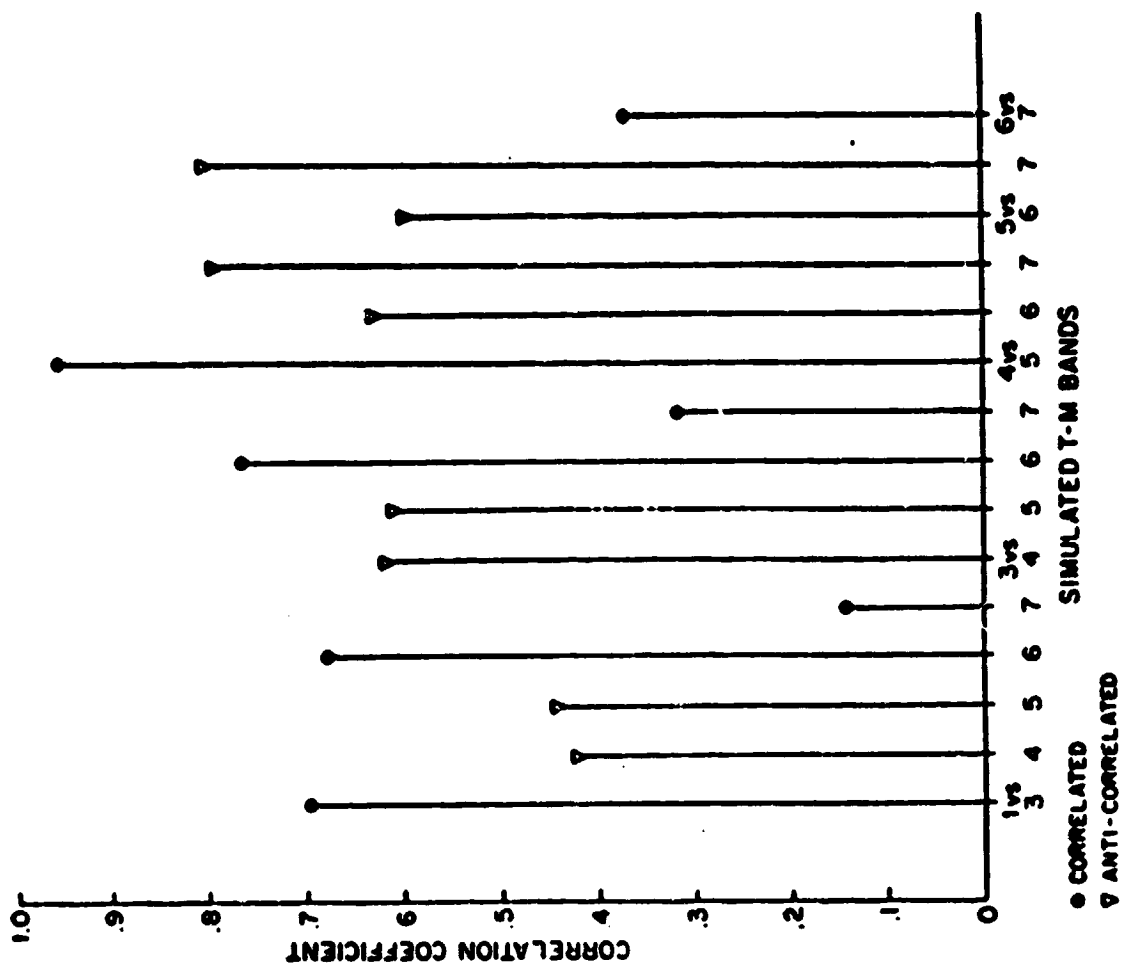
ones which have been heavily emphasized for consideration of
Thematic Mapper design. The GISS findings are significant,
and supportive of the contention that TM Bands 4 and 5 are
highly redundant.

Appendix

Linear Correlation Coefficients 24 Channel MSS Data

TABLE A1: FINNEY COUNTY, KANSAS, JUNE 9, 1975. FLIGHT LINE #1.
LINEAR CORRELATION COEFFICIENTS, UNCOMPENSATED DATA.

COMPARE WITH FIGURE 1 IN TEXT.

TM CHAN	MSS CHAN
1	3
3	6
4	8
5	9
6	12
7	20 & 21

Table A1 (continued): Finney County, Kansas, June 9, 1975. Flight Line #1. Linear correlation coefficients,

ALBEDO COMPENSATED DATA.

Compare with Figure 1 in text.

TM CHAN	MSS CHAN
1	3
3	6
4	8
5	9
6	12
7	20 & 21

Table A2: WILLIAMS COUNTY, NORTH DAKOTA. JUNE 22, 1975. FLIGHT LINE #2. LINEAR CORRELATION COEFFICIENTS, UNCOMPENSATED DATA. COMPARE WITH FIGURE 2 IN TEXT.

TM CHAN	MSS CHAN
1	3
3	6
4	8
5	9
6	12
7	20 & 21

TABLE A2 (CONTINUED): WILLIAMS COUNTY, NORTH DAKOTA. JUNE 22, 1975.

FLIGHT LINE #2. LINEAR CORRELATION COEFFICIENTS,

ALBEDO COMPENSATED DATA.

COMPARE WITH FIGURE 2 IN TEXT.

TM CHAN	MSS CHAN
1	3
3	6
4	8
5	9
6	12
7	20 & 21

TABLE A3: FINNEY COUNTY, KANSAS. JULY 6, 1975. FLIGHT LINE #1.
LINEAR CORRELATION COEFFICIENTS, UNCOMPENSATED DATA.
COMPARE WITH FIGURE 3 IN TEXT.

TM CHAN	MSS CHAN
1	3
3	6
4	8
5	9
6	12
7	20 & 21

TABLE A3 (CONTINUED): FINNEY COUNTY, KANSAS. JULY 6, 1975. FLIGHT LINE #1. LINEAR CORRELATION COEFFICIENTS, ALBEDO COMPENSATED DATA. COMPARE WITH FIGURE 3 IN TEXT.

TM CHAN	MSS CHAN
1	3
3	6
4	8
5	9
6	12
7	20 & 21

Table A4: Williams County, North Dakota. August 15, 1975. Flight Line #2. Linear correlation coefficients, uncompensated data.

Compare with Figure 4 in text.

TM CHAN	MSS CHAN
1	3
3	6
4	8
5	9
6	12
7	20 & 21

TABLE A4 (CONTINUED): WILLIAMS COUNTY, NORTH DAKOTA, AUGUST 15, 1975. FLIGHT LINE #2. LINEAR CORRELATION COEFFICIENTS, ALBEDO COMPENSATED DATA.

COMPARE WITH FIGURE 4 IN TEXT.

TM CHAN	MSS CHAN
1	3
3	6
4	8
5	9
6	12
7	20 & 21

TABLE A5 (PART ONE): WILLIAMS COUNTY, NORTH DAKOTA. AUGUST 15, 1975. FLIGHT LINE #2, PART ONE. LINEAR CORRELATION COEFFICIENT, ALBEDO COMPENSATED DATA.

COMPARE WITH FIGURE 5 IN TEXT.

TM CHAN	MSS CHAN
1	3
3	6
4	8
5	9
6	12
7	20 & 21

TABLE A5 (PART TWO): WILLIAMS COUNTY, NORTH DAKOTA. AUGUST 15, 1975. FLIGHT LINE #2, PART TWO. LINEAR CORRELATION COEFFICIENT, ALBEDO COMPENSATED DATA.

COMPARE WITH FIGURE 5 IN TEXT.

TM CHAN	MSS CHAN
1	3
3	6
4	8
5	9
6	12
7	20 & 21

TABLE A5 (PART THREE): WILLIAMS COUNTY, NORTH DAKOTA. AUGUST 15, 1975. FLIGHT LINE #2, PART THREE. LINEAR CORRELATION COEFFICIENT, ALBEDO COMPENSATED DATA. COMPARE WITH FIGURE 5 IN TEXT.

TM CHAN	MSS CHAN
1	3
3	6
4	8
5	9
6	12
7	20 & 21

TABLE A6: ALL SITES COMBINED. JUNE 9, JUNE 22, JULY 6, AUGUST 15, 1975. LINEAR CORRELATION COEFFICIENTS, UNCOMPENSATED DATA.

COMPARE WITH FIGURE 6 IN TEXT.

TM CHAN	MSS CHAN
1	3
3	6
4	8
5	9
6	12
7	20 & 21

TABLE A6 (CONTINUED): ALL SITES COMBINED. JUNE 9, JUNE 22, JULY 6, AUGUST 15, 1975. LINEAR CORRELATION COEFFICIENTS, ALBEDO COMPENSATED DATA.

COMPARE WITH FIGURE 6 IN TEXT.

TM CHAN	MSS CHAN
1	3
3	6
4	8
5	9
6	12
7	20 & 21